GNSS for HtMod

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Great Lakes Regional HtMod Forum
Lansing, MI
March 18, 2009

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GNSS data can be used to determine the ellipsoid height (h_P) of a point P.

h_P can be converted to the orthometric height (H_P) of P by the equation: $H_P = h_P - N_P$

where N_P equals the geoid height of P.

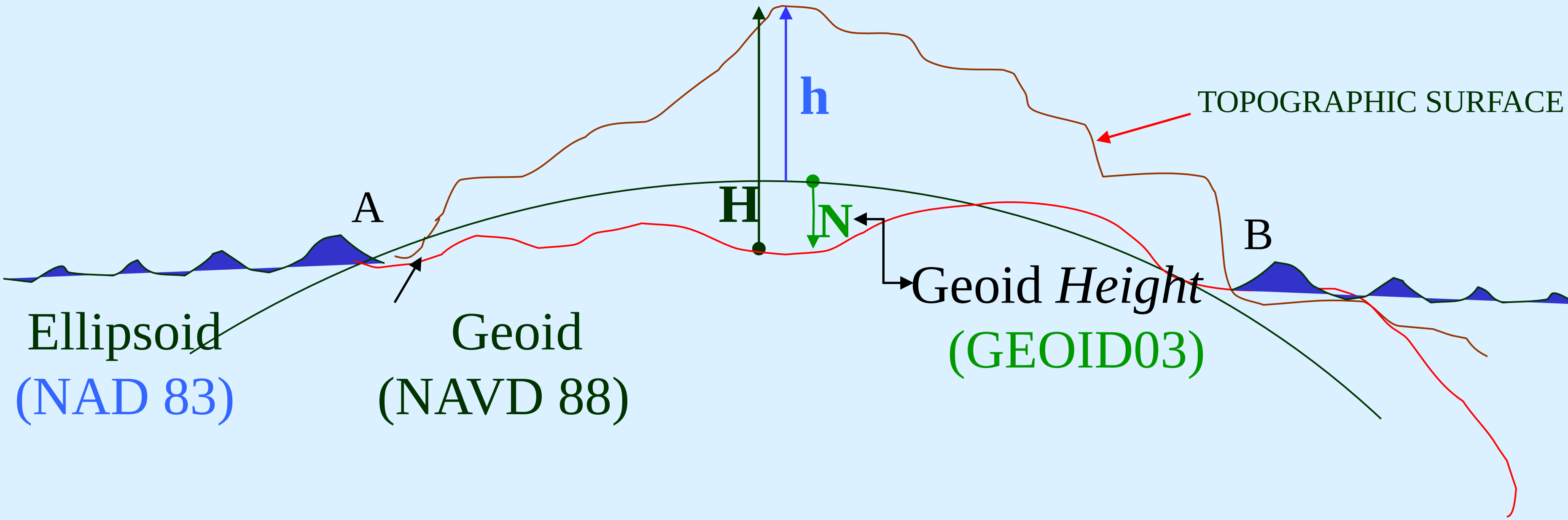
Ellipsoid, Geoid, and Orthometric Heights

H = Orthometric Height (NAVD 88)

h = Ellipsoidal Height (NAD 83)

N = Geoid Height (GEOID 03)

H = h - N



GNSS for HtMod

When using GNSS in differential mode,

the equation $H_P = h_P - N_P$

becomes $H_P = (h_P - h_o) + h_o - N_P$

or $H_P = dh + h_o - N_P$

where h_o *= the adopted ellipsoid height of some previously established geodetic reference station*

and dh = the measured difference in ellipsoid height between P and the geodetic reference station.

Estimating the Uncertainty in H_P

In accordance with the previous equation,
the standard error of H_P is given by the equation:

$$\sigma_{Hp} = (\sigma_{dh}^2 + \sigma_{ho}^2 + \sigma_{Np}^2)^{0.5}$$

Here σ_{dh} = the standard error of the measured ellipsoid height difference

σ_{ho} = the standard error of the adopted ellipsoid height of the geodetic reference station

σ_{Np} = the standard error of the geoid height at P.

Uncertainty Due to the Geoid Model

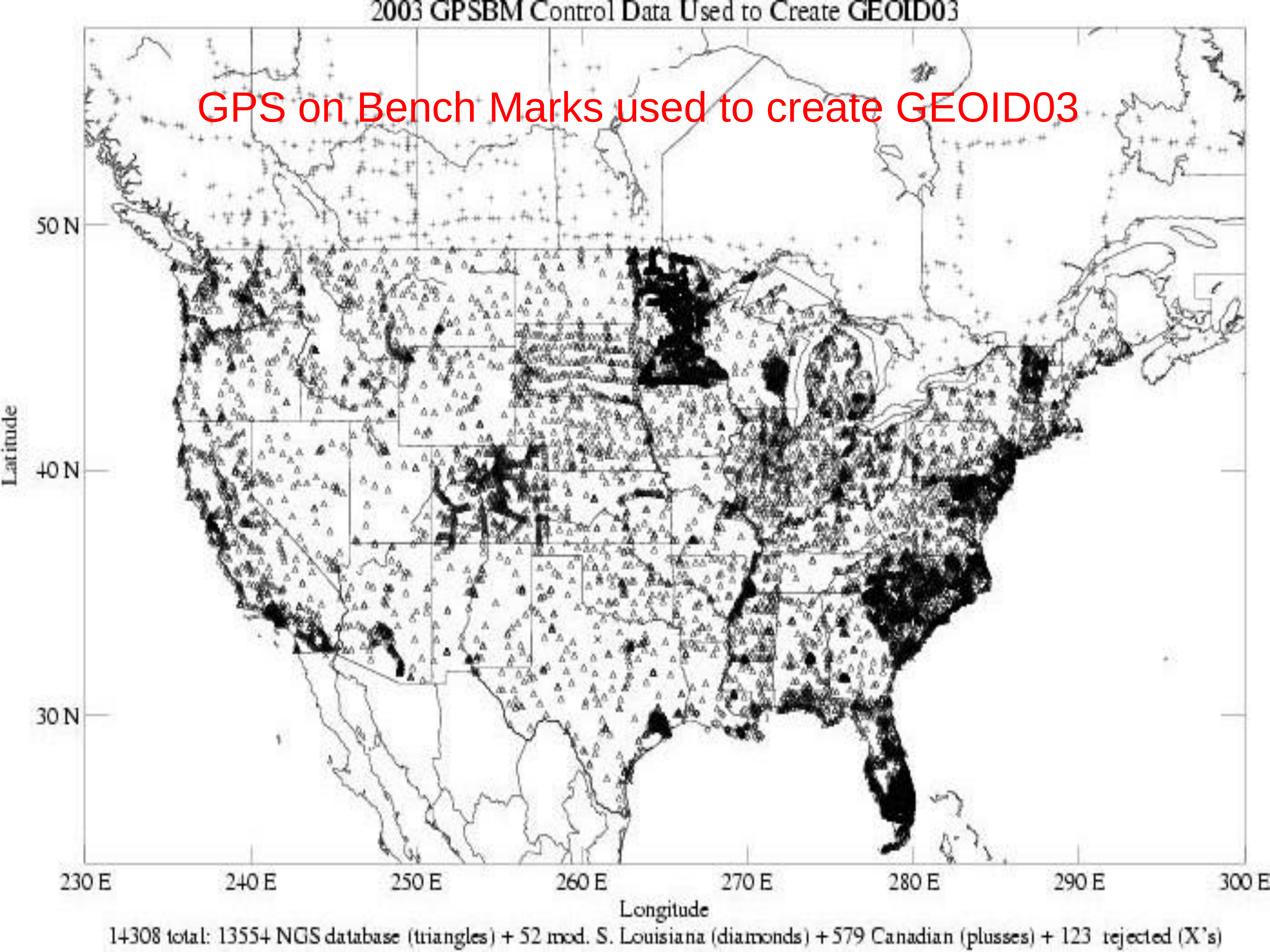
For GEOID03, $\sigma_{Np} \approx 2.4$ cm

For GEOID09, $\sigma_{Np} \approx 1.5$ cm

After GRAV-D, $\sigma_{Np} \leq 1.0$ cm

The above standard errors represent nominal values. Actual standard errors will vary geographically as a function of the local geometry of reference stations that have both accurate orthometric heights and accurate ellipsoid heights.

GPS on Bench Marks used to create GEOID03



Considering Different GNSS Technologies

We will now consider values for σ_{dh} and σ_{ho} for the following technologies:

- Positioning P relative to a passive reference station
- Positioning P relative to the CORS network using OPUS-S
- Positioning P relative to the CORS network using OPUS-RS
- Positioning P using network RTK technology

Positioning P Relative to a Passive Reference Station

According to Eckl et al. (2001), $\sigma_{dh} = 3.7 \text{ cm} / (T)^{0.5}$

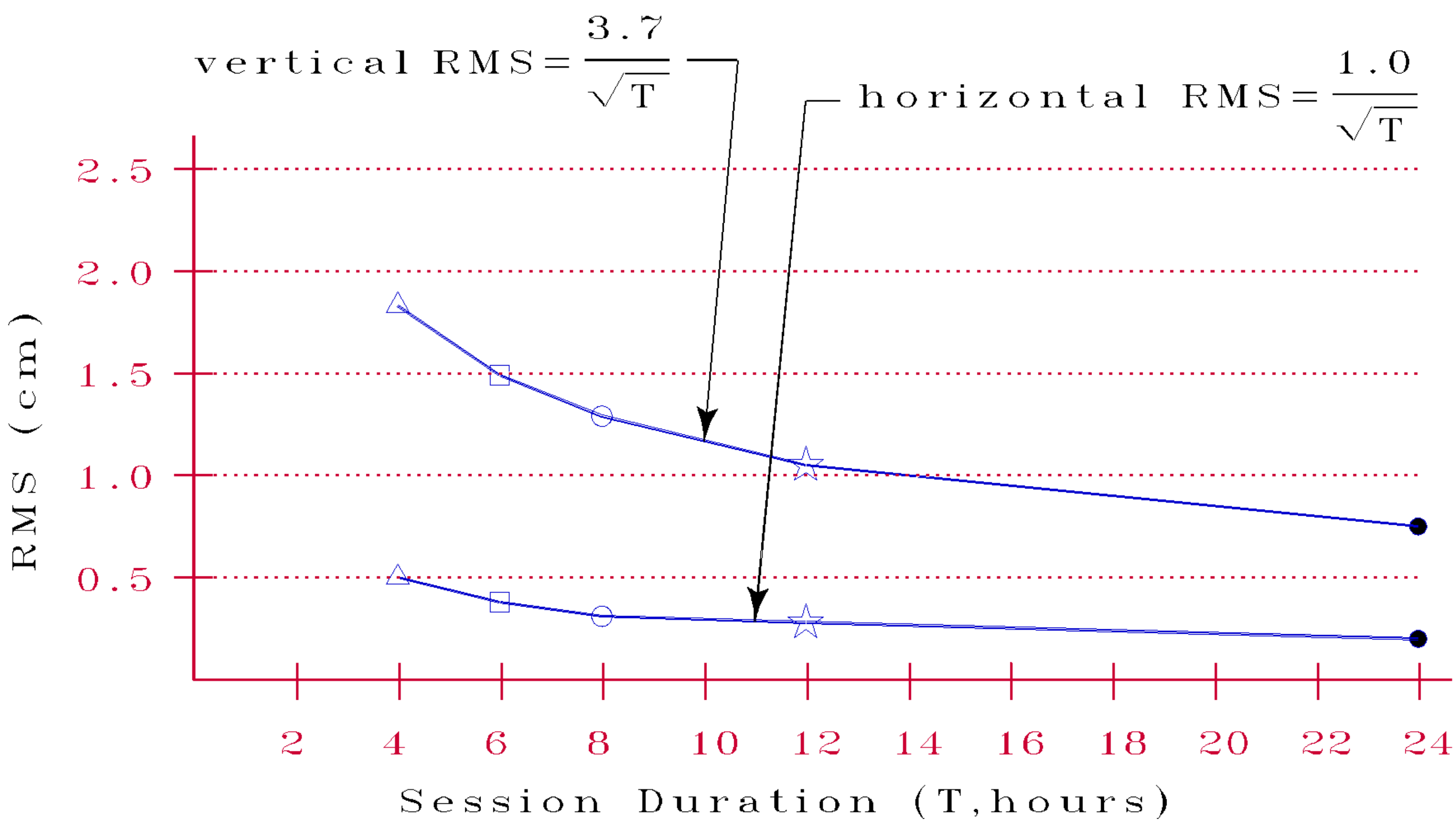
when $T \geq 4$ hours and the baseline length ≥ 25 km.

Here T = the duration of the observing session.

Thus $\sigma_{dh} = 1.85$ cm, when T = 4 hours.

$\sigma_{ho} \leq 2.0$ cm for many of the passive reference stations that participated in the NAD 83 (NSRS2007) adjustment. (There is a significant concern about unknown vertical crustal motion.)

Positioning Error vs. Duration of the Observing Session



Positioning P relative to the CORS Network Using OPUS-S

Again $\sigma_{dh} = 3.7 \text{ cm} / (T)^{0.5}$

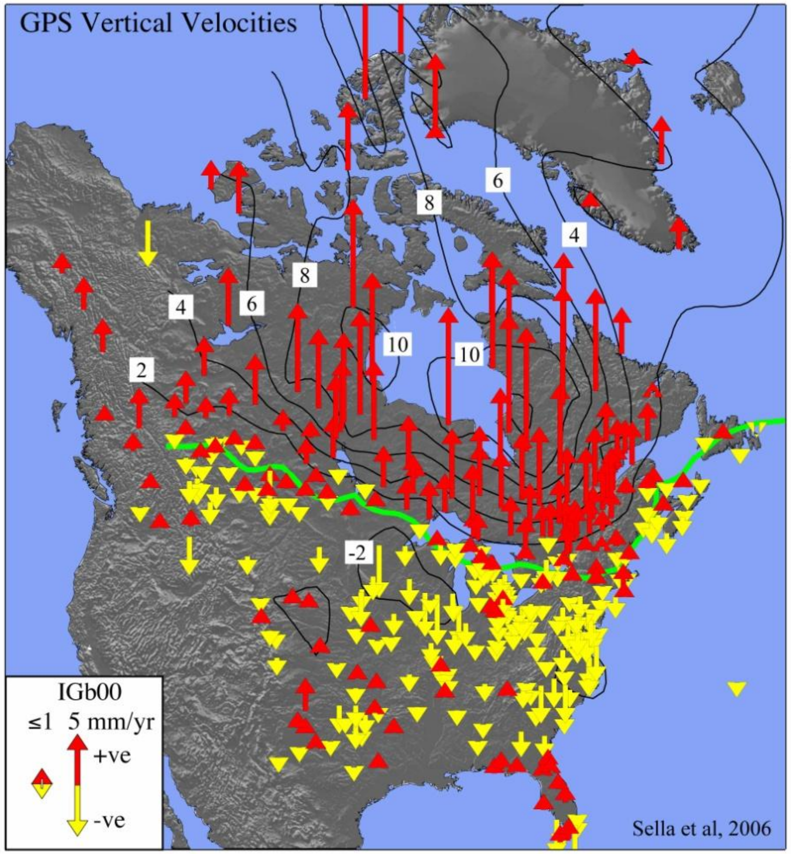
But OPUS-S can work for $T \geq 2$ hours

Thus, $\sigma_{dh} = 2.6$ cm when $T = 2$ hours.

Because OPUS-S uses three CORS and because CORS vertical velocities are known

$$\sigma_{ho} \leq 1.0 \text{ cm}$$

CORS for Monitoring Vertical Crustal Motion



Vertical velocities associated with Glacial Isostatic Adjustment

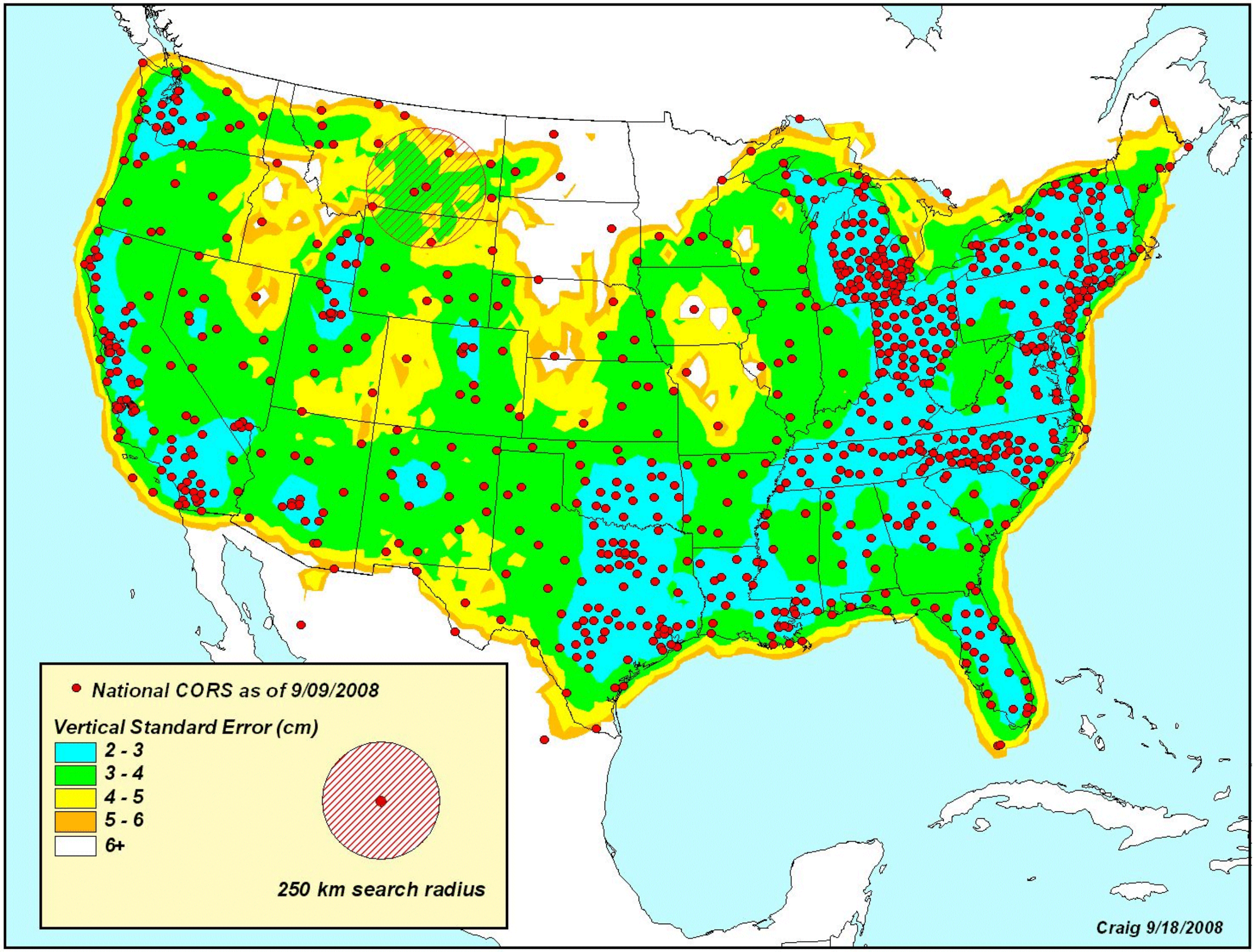
Positioning P Relative to the CORS Network Using OPUS-RS

σ_{dh} depends on the local geometry of the CORS network because OPUS-RS is interpolating the atmospheric refraction conditions measured at nearby CORS to estimate the corresponding refraction conditions at P.

For most of CONUS, $2.0 \text{ cm} \leq \sigma_{dh} \leq 4.0 \text{ cm}$

Again, $\sigma_{ho} \leq 1.0 \text{ cm}$ because OPUS-RS uses many CORS and because CORS velocities have been determined.

Vertical standard error achievable in CONUS when a user submits 15 minutes of GPS data to OPUS-RS



Positioning P Using Network RTK Technology

According to a recent (Nov. 2008) study by Newcastle University

$$1.3 \text{ cm} \leq \sigma_{dh} \leq 2.6 \text{ cm}$$

when a person performs two 3-minute sessions spaced at least 20 minutes apart, provided

- Good network geometry (P is inside polygon formed by RTK network)
- No significant multipath
- GDOP ≤ 3
- Software indicates good "coordinate quality"

Again, $\sigma_{ho} \leq 1 \text{ cm}$

Note: The use of two sessions averages satellite geometry, multipath, and atmospheric refraction.

Positioning P Using Network RTK Technology

According to the study by Newcastle University:

The use of GPS+GLONASS does not improve on the accuracy achievable using GPS only.

However, the use of GPS+GLONASS allows RTK surveying to proceed with less downtime, especially in areas where sky visibility is somewhat obstructed.

Summary

Technology	T	σ_{dh} (cm)	σ_{ho} (cm)	σ_{Np} (cm)	σ_{Hp} (cm)
Passive Ref. Stations	4 hr	1.85	2.0	1.5	3.1
CORS & OPUS-S	4 hr	1.85	1.0	1.5	2.6
CORS & OPUS-S	2 hr	2.6	1.0	1.5	3.2
CORS & OPUS-RS	15 min	2.0 – 4.0	1.0	1.5	2.7 – 4.4
Network RTK	2 times 3 min	1.3 – 2.6	1.0	1.5	2.2 – 3.2